

5.0 PRE-OPERATIONAL TESTING PROGRAM

40 CFR 146.82(a)(8), 146.87

MARQUIS BIOCARBON PROJECT

Facility Information

Facility name: MARQUIS BIOCARBON PROJECT

Facility contact: ELIZABETH STEINHOUS
DIRECTOR OF ENVIRONMENTAL AFFAIRS
10000 MARQUIS DRIVE, HENNEPIN, IL 61327
815.925.7300 / BETHSTEINHOUS@MARQUISENERGY.COM

Well name: MCI CCS 3

Well location: PUTNAM COUNTY, ILLINOIS

Non Responsive -- Geological information

Table of Contents

5.0	Pre-Operational Formation Testing Program.....	4
5.1	Introduction	4
5.2	MCI MW 1 Well Testing and Wireline Logging.....	6
5.2.1	Well Logging: Surface Section.....	6
5.2.2	Well Logging: Intermediate Section.....	6
5.2.3	Well Logging: Deep Section.....	7
5.2.4	Core Program	8
5.2.5	Fluid Sampling and Analysis.....	10
5.2.6	Geomechanical Testing.....	11
5.2.7	Hydrogeologic Characteristics of the Mt. Simon Sandstone.....	15
5.3	Pre-Operational Testing during the Installation of the MCI CCS 3 Well (146.87 (a))..	17
5.3.1	Deviation Surveys (146.87 (a)(1))	17
5.3.2	Well Logging: Surface Section (146.87 (a)(2))	17
5.3.3	Well Logging: Intermediate Section (146.87 (a)(2))	18
5.3.4	Well Logging: Deep Section (146.87 (a)(3)).....	19
5.3.5	MCI CCS 3 Well Mechanical Integrity Testing (146.87 (a)(4))	20
5.4	MCI CCS 3 Well Core Program (146.87 (b)(d))	21
5.5	MCI CCS 3 Well: Fluid Sampling and Analysis (146.87 (b – d)).....	22
5.6	MCI CCS 3 Well Geomechanical Testing (146.87 (d)).....	22
5.7	MCI CCS 3 Well Hydrogeologic Characteristics (146.87 (e))	22
5.8	MCI CCS 3 Well Schedule (146.87 (f)).....	23

List of Figures

Figure 5-1: Locations of the proposed injection well (MCI CCS 3), the characterization well MCI MW-1, and an above confining zone (ACZ) monitor well (MCI ACZ 1).....	5
Figure 5-2: Sidewall core (SWC), Whole Core (Core), and Drill Stem Test (DST) sample locations with wireline log data from MCI MW 1	14
Figure 5-3: Tentative drilling schedule for the injection well	24

List of Tables

Table 5-1: Summary of wireline logs and associated parameters and depth intervals of logging tools ran before and after surface casing (surface to 410 ft) in the characterization well.	6
Table 5-2: Summary of wireline logs and associated parameters of logging tools to be run before and after intermediate casing (410 to 2,756 ft) in the characterization well.....	7
Table 5-3: Summary of wireline logs and associated parameters of logging tools ran in the deep section (2,756 to 4,990 ft, MD) of the characterization well (MCI MW 1).	8
Table 5-4: Whole core (upper) and sidewall core (lower) sample locations and sizes collected from the characterization well (MCI MW 1).	9
Table 5-5: Summary of core analyses, associated parameters, and sample intervals in the characterization well (MCI MW 1).....	10
Table 5-6: Sampling intervals and analytical parameters from the characterization well.	11
Table 5-7: Geomechanical characterization in-situ field tests conducted, and parameters collected during the installation of the characterization well.	13
Table 5-8: Reservoir tests and parameters collected in the Mount Simon Sandstone during the installation of the characterization well (MCI MW 1).....	16
Table 5-9: Deviation survey frequencies to be taken in the injection well.....	17
Table 5-10: Summary of wireline logs and associated parameters of logging tools to be run before and after surface casing (surface to 350 ft) in the injection well.	18
Table 5-11: Summary of wireline logs and associated parameters of logging tools to be run before and after intermediate casing (350 to 2,750 ft) in the injection well.	19
Table 5-12: Summary of wireline logs and associated parameters of logging tools to be run before and after long string casing (2,750 to 5,000 ft, MD) in the injection well.	20
Table 5-13: Tentative drilling schedule for the injection well MCI CCS 3.....	25

5.0 Pre-Operational Formation Testing Program

5.1 Introduction

This section describes the pre-operational formation testing program implemented to characterize the chemical and physical features of the injection zone and confining zone at the Marquis BioCarbon Project. The pre-operational testing program meets the testing requirements of Title 40 of the U.S. Code of Federal Regulations Section 146.87 (40 CFR 146.87) and well construction requirements of 40 CFR 146.86. The pre-operational testing program provides and verifies the depth, thickness, mineralogy, lithology, porosity, permeability, and geomechanical information of the Mt. Simon Sandstone (carbon dioxide [CO₂] storage formation), the overlying Eau Claire Shale (confining layer), and other relevant geologic formations. In addition, pre-operational testing data are used to provide baseline information for the site that will be used for comparative purposes throughout the project. For example, fluid samples collected during the pre-operation testing will be used as a reference to identify geochemical changes in samples collected during injection operation that may result from the injection of CO₂.

Well (MCI MW 1) was drilled in Q4 of 2021 (Permit No. 010858) and was used to provide the pre-operational testing information. This well is located 1.2 miles northwest of the proposed injection location (Figure 5-1). Marquis will use the MCI MW 1 well as a far field monitoring well under the Class VI program. Limited additional pre-operational testing data will be generated during the installation of the MCI CCS 3 well, but most of the data collected during the installation of the MCI CCS 3 well will be used for comparative purposes to the MCI MW 1 well data to confirm homogeneity across the site.

This document describes the extensive and complete logging, coring, fluid sampling, and formation hydrogeologic testing that was performed in the MCI MW 1 well. The data generated from the pre-operational testing performed on MCI MW 1 has been provided in the Project Narrative (Permit Section 1) and has been incorporated into the site static earth and dynamic models (Permit Section 2). This section also describes the planned program for confirmation and final data gathering in the MCI CCS 3 well. These data may also provide baseline information for the characteristics of the site and specific methods for baseline data collection are provided in the Testing and Monitoring Plan (Permit Section 7).

Non Responsive -- Geological information

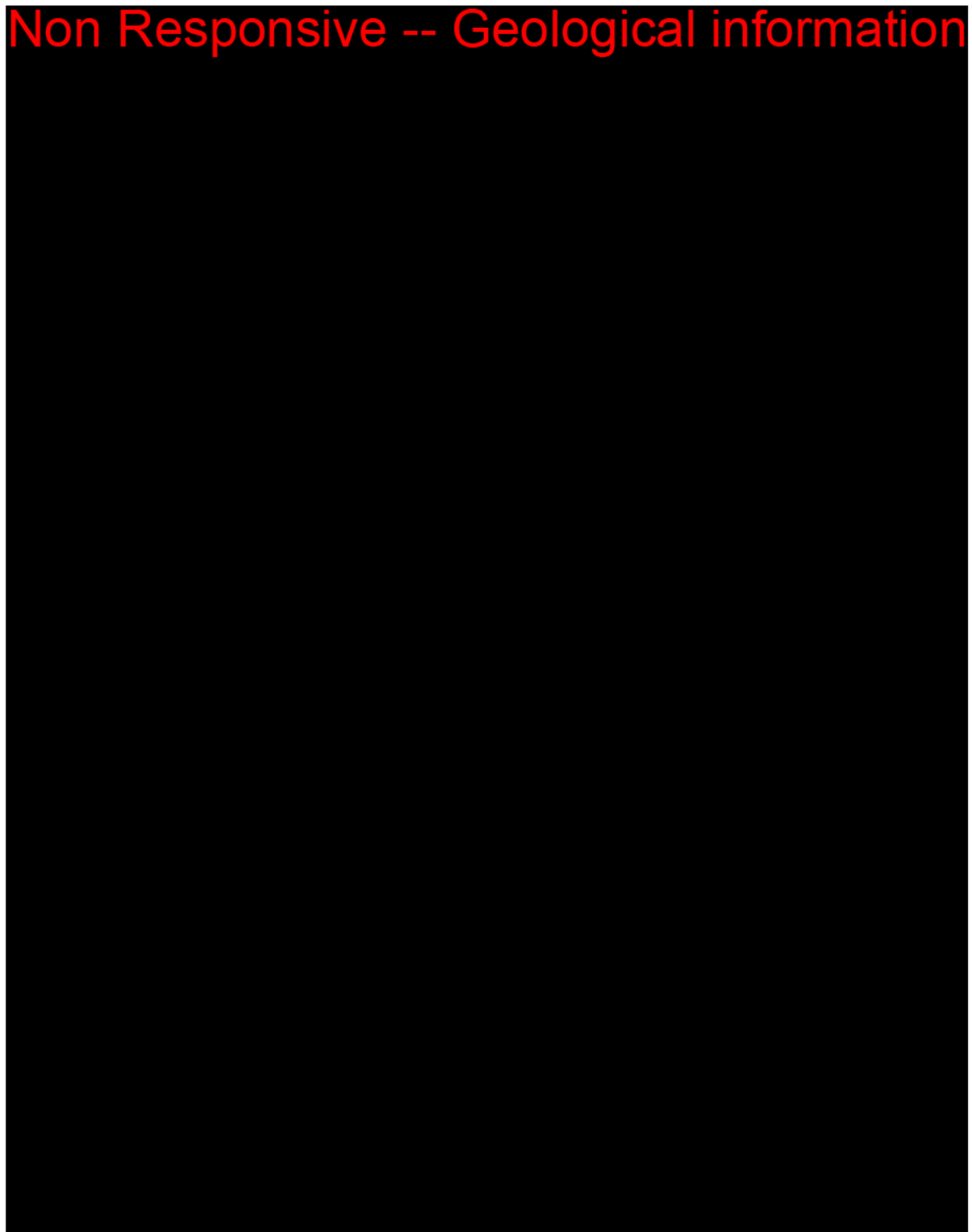


Figure 5-1: Locations of the proposed injection well (MCI CCS 3), the characterization/monitoring well (MCI MW-1), and an above confining zone (ACZ) monitor well (MCI ACZ 1).

5.2 MCI MW 1 Well Testing and Wireline Logging

This section provides details for the collection of samples and data from the MCI MW 1 well that was installed in Q4 of 2021. The results of the sample analysis and data processing are presented in the Project Narrative (Permit Section 1) and the results have been incorporated in the static and dynamic models provided in the Area of Review (AoR) section (Permit Section 2).

5.2.1 Well Logging: Surface Section

Prior to setting surface casing at 410 feet (ft) measured depth (MD), open hole logs were acquired from surface to total depth (TD) (410 ft), including gamma ray, density, neutron porosity, spontaneous potential (SP), resistivity, dipole sonic – delta time (DT), and caliper logs. Table 5-1 summarizes the well logs that were acquired before and after surface casing was set and the parameters obtained from each well log.

After setting surface casing and waiting 24 hours for the cement to set, a cement bond log - variable density log (CBL-VDL) was acquired with a gamma ray tool for depth correlation to evaluate the cement integrity (Table 5-1).

Open/ Cased Hole	Log Type	Parameters Obtained
Open Hole	Gamma Ray	Lithology
	Density	Porosity, Density
	Neutron Porosity	Porosity
	Spontaneous Potential	Permeability
	Resistivity	Fluid Saturation, Permeability
	Dipole Sonic - DT	Porosity, Formation Velocities
	Caliper	Borehole Diameter, Stress
Cased Hole	Cement Bond Log - Variable Density Log	Cement Integrity

Table 5-1: Summary of wireline logs and associated parameters and depth intervals of logging tools run before and after surface casing (surface to 410 ft) in the MCI MW 1 well.

5.2.2 Well Logging: Intermediate Section

Open hole well logs were acquired in the intermediate section of the well from 410 to 2,756 ft MD to characterize the deeper geology. Open hole logs included caliper, gamma ray, spectral gamma ray, SP, resistivity, neutron porosity, density, and dipole sonic. Table 5-2 summarizes the well logs acquired in the intermediate well section and the purpose of each well log.

After the intermediate casing string was cemented, a CBL-VDL and an advanced ultrasonic logging tool were run with a gamma ray tool for depth correlation to evaluate the quality of the cement behind the intermediate casing (Table 5-2).

Open/ Cased Hole	Log Type	Parameters Obtained
Open Hole	Caliper	Borehole Diameter, Stress
	Gamma Ray	Lithology
	Spectral Gamma Ray	Lithology, Mineralogy
	Spontaneous Potential	Permeability
	Resistivity	Fluid Saturation, Permeability
	Neutron Porosity	Porosity
	Density	Porosity, Density
	Dipole Sonic – DT & Cross Dipole	Porosity, Formation Velocities, Ductility, Stress, Poisson's Ratio, Young's Modulus
Cased Hole	Cement Bond Log - Variable Density Log	Cement Integrity
	Ultrasonic Cement Evaluation	Cement Integrity

Table 5-2: Summary of wireline logs and associated parameters of logging tools to be run before and after intermediate casing (410 to 2,756 ft) in the MCI MW 1 well.

5.2.3 Well Logging: Deep Section

Open hole well logs were acquired in the deep section of the well (2,756 to 4,990 ft MD) after the drilling the borehole to TD to characterize the geology in this section of the well. Open hole logs included caliper, gamma ray, spectral gamma ray, temperature, SP, resistivity, neutron porosity, density, dipole sonic, nuclear magnetic resonance (NMR), elemental neutron, and resistivity and acoustic image logs. Table 5-3 summarizes the well logs that were acquired in the deep section of the borehole and the purpose of each well log. No casing was installed in across the deep section of the borehole; therefore, no cased hole logs were acquired from the deep section of the well.

Open/ Cased Hole	Log Type	Parameters Obtained
Open Hole	Caliper	Borehole Diameter, Stress
	Gamma Ray	Lithology
	Spectral Gamma Ray	Lithology, Mineralogy
	Temperature	Temperature
	Spontaneous Potential	Permeability
	Resistivity	Fluid Saturation, Permeability
	Neutron Porosity	Porosity
	Density	Porosity, Density, Acoustic Impedance
	Dipole Sonic – DT & Cross Dipole	Porosity, Formation Velocities, Acoustic Impedance, Ductility, Stress, Poisson's Ratio, Young's Modulus
	Nuclear Magnetic Resonance	Porosity, Permeability, Pore size distribution
	Elemental Neutron	Lithology, Mineralogy
	Image Log	Lithology, Porosity, Borehole Diameter, Fracture Characterization, Stress

Table 5-3: Summary of wireline logs and associated parameters of logging tools ran in the deep section (2,756 to 4,990 ft, MD) of the MCI MW 1 well.

5.2.4 Core Program

Table 5-4 summarizes the whole and sidewall core acquisition in the MCI MW 1 well. Eight intervals of whole, 4-inch core were acquired from the Eau Claire Formation and Mt. Simon Sandstone. Twenty-nine sidewall core locations were selected based on the open hole log data to fill any gaps in the whole core program. The sidewall cores collected provided a comprehensive set of rock property data for calibrating geophysical wireline logs and supplemented formation property data where whole core data were not available. Core depths were calibrated to wireline logs based on the gamma ray response.

Core testing provided information on rock properties (e.g., porosity, permeability, petrology, and mineralogy) that are representative of the injection and confining zones at the CO₂ injection site. Table 5-5 details the laboratory testing, and the data from the core analyses are included in the Project Narrative and AoR sections (Permit Sections 1 and 2).

Whole Cores	Formation	Depth (ft, MD)	Notes
1	Eau Claire (U)	2,800-2,820	10' recovered, 50%
2	Eau Claire (M)	2,880-2,900	20' recovered, 100%
3	EC/Mt Simon Contact	3,045-3,065	19.6' recovered, 98%
4	Mt Simon	3,370-3,390	20' recovered, 100%
5	Mt Simon	3,700-3,720	19.8' recovered, 99%
6	Mt Simon	4,100-4,120	18.2' recovered, 91%
7	Mt Simon	4,575-4,595	15.8' recovered, 79%
8	Mt Simon	4,802-4,822	20' recovered, 100%

Sidewall Cores					
Depth (ft, MD)	Formation	Comments	Depth (ft, MD)	Formation	Comments
2,920	Eau Claire	1.5 in	4,523	Mt Simon	1 in
3,014.5	Elmhurst	1.5 in	4,530	Mt Simon	1 in
3,073	Elmhurst	1.5 in	4,550	Mt Simon	1 in
3,150	Mt Simon	1.5 in	4,560	Mt Simon	1 in
3,187	Mt Simon	1.5 in	4,571	Mt Simon	1 in
3,268	Mt Simon	1.5 in	4,608	Mt Simon	1 in
3,320	Mt Simon	1.5 in	4,618.5	Mt Simon	1 in
3,437	Mt Simon	1.5 in	4,646	Mt Simon	1 in
3,558	Mt Simon	1.5 in	4,665.5	Mt Simon	1 in
3,600	Mt Simon	1.5 in	4,693	Mt Simon	1 in
3,655	Mt Simon	1.5 in	4,720	Mt Simon	1 in
3,975	Mt Simon	1 in	4,773	Mt Simon	1 in
3,975	Mt Simon	1 in	4,871	Pre-Cambrian	1 in
4,045	Mt Simon	1 in	4,878	Pre-Cambrian	1 in
4,365	Mt Simon	1 in			

Table 5-4: Whole core (upper) and sidewall core (lower) sample locations and sizes collected from the MCI MW 1 well.

Core Analysis Type	Sample/Test Interval	Parameters Obtained
Routine Core Analysis	Eau Claire Fm., Mt. Simon Sandstone	Porosity, Permeability, Grain Density
Threshold Entry Pressure	Eau Claire Fm.	Seal Capacity, Displacement Pressure
X-Ray Fluorescence	Eau Claire Fm., Mt. Simon Sandstone	Elemental Composition
Thin-Section Petrography	Eau Claire Fm., Mt. Simon Sandstone	Mineralogy, Lithology, Porosity, Grain size, Textural maturity, Oil Staining
X-Ray Diffraction	Eau Claire Fm., Mt. Simon Sandstone	Mineralogy, clay identification
Core Gamma Ray Log	Eau Claire Fm., Mt. Simon Sandstone	Lithology, Geologic Contacts
Relative Permeability	Mt. Simon Sandstone	Two-fluid phase permeability and fractional flow
Mercury Injection Capillary Pressure	Eau Claire Fm., Mt. Simon Sandstone	Capillary Pressure, Relative permeability, Wettability, Rock Typing
Triaxial Tests	Eau Claire Fm., Mt. Simon Sandstone	Rock Strength, Ductility, Poisson's Ratio, Young's Modulus
Rock Compressibility	Mt. Simon Sandstone	Rock Compressibility

Table 5-5: Summary of core analyses, associated parameters, and sample intervals in the MCI MW 1 well.

5.2.5 Fluid Sampling and Analysis

Samples were collected from the MCI MW 1 well in several formations to confirm the deepest underground source of drinking water (USDW)-bearing formation and to determine the baseline geochemistry of the subsurface fluids. USDWs are defined as having total dissolved solids (TDS) of less than 10,000 parts per million (ppm).

During the installation of the MCI MW 1 well, representative fluid samples were collected via drill stem tests (DSTs) and pumping from deeper water-bearing formations. Target geologic formations for water sampling included the St. Peter Sandstone, New Richmond Sandstone, Gunter Sandstone, Galesville Sandstone, and the Mt. Simon Sandstone. The analytical results for the samples collected from above the caprock (Eau Claire Formation) were used to confirm the deepest USDW formation and the primary analyte for these samples was TDS. Additional analyses, such as major cations/anions, pH, alkalinity, specific gravity, conductance, and stable carbon (C), oxygen (O), and hydrogen (H) isotopes, were performed on the above confining zone samples as well as the samples collected from the Mt. Simon Sandstone to provide baseline geochemical data for these formation fluids as part of the Testing and Monitoring Plan (Permit Section 7).

Through the chemical analyses on the fluid samples collected above the caprock formation, it has been determined that the Gunter Sandstone is the deepest USDW with a TDS concentration of 665 mg/L, while the Galesville Sandstone has a TDS value of approximately 24,000 mg/L. Additional discussion of the analytical results is provided in the Project Narrative (Permit Section 1).

Fluid Sample Depth (ft, MD)	Formation	Analytical Parameters
1,480 - 1,530	St. Peter Sandstone	TDS, major cations/anions, trace metals, pH, alkalinity, specific gravity, conductance, stable C, O, H isotopes, ¹⁴ C
1,867 - 1,950	New Richmond	TDS, major cations/anions, trace metals, pH, alkalinity, specific gravity, conductance, stable C, O, H isotopes, ¹⁴ C
2118 - 2154	Gunter	TDS, major cations/anions, trace metals, pH, alkalinity, specific gravity, conductance, stable C, O, H isotopes, ¹⁴ C
2,651 - 2,673	Galesville Sandstone	TDS, major cations/anions, trace metals, pH, alkalinity, specific gravity, conductance, stable C, O, H isotopes, ¹⁴ C
3,370 - 3,390	Mt. Simon Sandstone	TDS, major cations/anions, trace metals, pH, alkalinity, specific gravity, conductance, stable C, O, H isotopes, ¹⁴ C
4,100 - 4,120	Mt. Simon Sandstone	TDS, major cations/anions, trace metals, pH, alkalinity, specific gravity, conductance, stable C, O, H isotopes, ¹⁴ C
4,575 - 4,595	Mt. Simon Sandstone	TDS, major cations/anions, trace metals, pH, alkalinity, specific gravity, conductance, stable C, O, H isotopes, ¹⁴ C
4,802 - 4,822	Mt. Simon Sandstone	TDS, major cations/anions, trace metals, pH, alkalinity, specific gravity, conductance, stable C, O, H isotopes, ¹⁴ C

Table 5-6: Sampling intervals and analytical parameters from the MCI MW 1 well.

5.2.6 Geomechanical Testing

The objective of the geomechanical characterization program is to use data from the wireline logs, core analyses, and field geomechanical testing to provide information regarding the direction and magnitude of the three principal components of the stress field (σ_h , σ_H , σ_v), confined compressive strength, ductility, and fracture pressure for the project site.

Well logs were used to constrain geomechanical characteristics of the Eau Claire and Mt. Simon Formations. The well logs that were used to derive geomechanical properties include gamma ray, image, elemental spectroscopy, and dipole sonic logs (Tables 5-2 and 5-3).

Whole core samples collected from the Eau Claire and Mt. Simon Formations were used in laboratory analyses for triaxial testing to determine parameters such as confined compressive strength, tensile strength, and ductility.

Field geomechanical tests (minifrac testing) were conducted to provide an accurate measurement of the fracture pressure in both the overlying confining zone and storage formation (Table 5-7). The data from the in-situ field tests were integrated with the well log data and laboratory measurements of mechanical properties from selected core samples to characterize the confining layer and injection zones.

The key objective of the mini-frac tests is to determine the magnitude of the minimum horizontal principal stress, S_h , which is required to determine the maximum acceptable pressure for injecting CO₂ into reservoir and to avoid hydraulic fracturing within the injection reservoir and within the overlying caprock or underlying zones crystalline basement sequences.

Mini-frac testing was performed at six depth intervals in the MCI MW 1 well (two intervals in the Eau Claire and four intervals in the Mt. Simon Sandstone) using a multiple injection cycle approach. The mini-frac test data were then analyzed to determine the Formation Breakdown Pressure (FBP), Instantaneous Shut-In Pressure (ISIP), Fracture Propagation Pressure (FPP), and Fracture Closure Pressure (FCP) Based on the test data, the FPP gradient was determined to be 0.76 psi/ft, and this value was used in the modeling and maximum allowable injection pressure (described in Section 2 of this permit application).

Data from the geomechanical testing performed on the MCI MW 1 well has been incorporated into the static and dynamic models detailed in the AoR and Corrective Action Plan (Permit Section 2) and the data are presented in the Project Narrative (Permit Section 1).

Formation	Target Depth (ft, MD)	Test	Parameters Obtained
Eau Claire Shale	2,834 - 2,846 2,936 - 2,947 2,970 - 2,982	Mini-Frac Test	Fracture Pressure
	2,805, 2,884, 2,889, 2,896, 3,047, 3,050, 3,053, 3,059	Triaxial Test	Rock strength, Ductility, Poisson's Ratio, Young's Modulus
	Full Interval	Dipole Sonic & Cross Dipole Log	Ductility, Stress, Poisson's Ratio, Young's Modulus
	Full Interval	Caliper	Stress Direction
	Full Interval	Image Log	Fracture characterization, stress

Mt. Simon Sandstone	3,270 - 3,282, 3,852 - 3,864, 4,410 - 4,422, 4,684 - 4,696	Mini-Frac Test	Fracture Pressure
	3,710, 4,105	Triaxial Test	Rock strength, Ductility, Poisson's Ratio, Young's Modulus
	3,350	Rock Compressibility	Rock Compressibility
	Full Interval	Dipole Sonic & Cross Dipole Log	Ductility, Stress, Poisson's Ratio, Young's Modulus
	Full Interval	Caliper	Stress Direction
	Full Interval	Image Log	Fracture characterization, stress

Table 5-7: Geomechanical characterization in-situ field tests conducted, and parameters collected during the installation of the MCI MW1 well.

Non Responsive -- Geological information

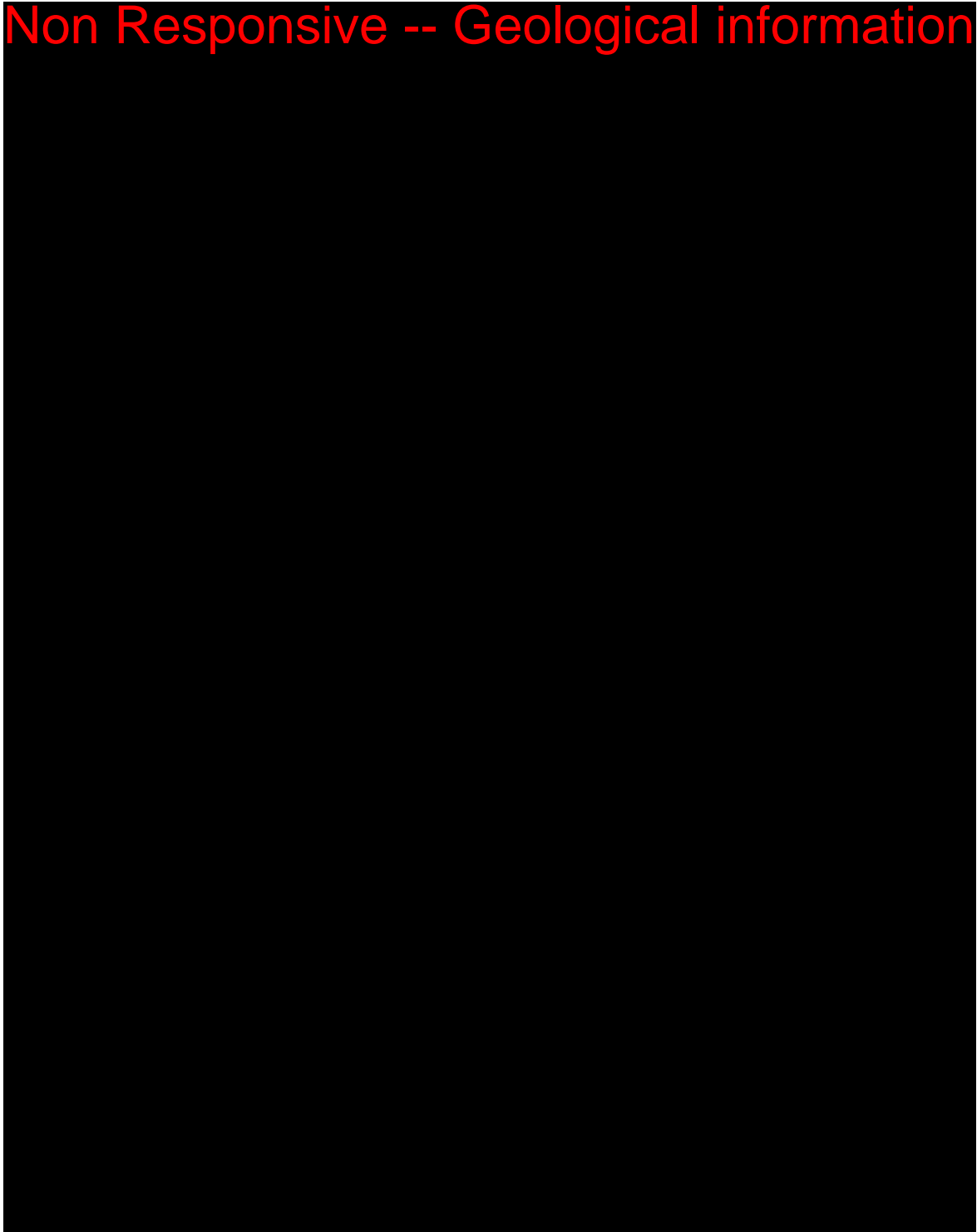


Figure 5-2: Sidewall core (SWC), Whole Core (Core), and Drill Stem Test (DST) sample locations with wireline log data from MCI MW 1

5.2.7 Hydrogeologic Characteristics of the Mt. Simon Sandstone

The following tests were performed on the MCI MW 1 well to evaluate the hydrogeologic characteristics of the storage formation:

- Drill Stem Tests (DSTs)
- Pump or injectivity tests, coupled with pressure fall-off monitoring
- Flowmeter logging.

DSTs can be injection tests or pumping tests; both were performed as part of the MCI MW 1 characterization. These tests are performed by isolating the zone of interest with open borehole packers. These tests provide estimates of hydrologic properties in the region near the wellbore, such as initial formation pressure, transmissivity, average hydraulic conductivity, storativity, and borehole skin effects.

Four DSTs were performed for hydraulic characterization in the Mt. Simon Sandstone during the drilling of the MCI MW 1 well (Table 5-8). Additional DSTs were performed in the above confining zone formations. These DSTs were focused on the collection of fluid samples from these formations to confirm USDW depth and to have a baseline for future sample measurements.

Pressure fall-off (PFO) testing involves the measurement and analysis of pressure data from a zone in a well after it has been shut in following a period of injection. PFOs provide valuable information on parameters such as borehole skin effects, injectivity, transmissivity, formation boundary conditions, and average permeability; that can be used to characterize the storage formation and constrain the dynamic model. PFO testing was performed at five intervals (including the composite Mt. Simon test) in the Mt. Simon formation to determine the hydraulic properties of the reservoir, as listed above. The PFO testing followed periods of injection, and the duration was dependent upon the time required for the pressure to return to near-baseline conditions. The data from the PFO were incorporated into the models for the injection site described in the AoR and Corrective Action Plan (Permit Section 1) and the Project Narrative (Permit Section 2) of this permit application.

Flowmeter logging is a method for identifying zones of fluid inflow or outflow within an open borehole. A flowmeter logging survey is conducted by running a wireline-deployed flowmeter logging tool across the open borehole section under static and dynamic conditions. Dynamic logging runs are conducted while either injecting fluid into the well or withdrawing (i.e., pumping) fluid from the well at a constant rate. Typically, several logging passes are made at different constant logging speeds (e.g., 30 to 60 ft/minute). For most testing applications, commercially available mechanical flowmeters can be used successfully. Temperature, density, and pressure probes run in conjunction with the flowmeter provide additional information to help identify zones of fluid entry into the borehole.

Two separate dynamic flow (flowmeter) tests were performed across the open borehole of the MCI MW 1 well following the other hydrogeologic testing. These flowmeter tests were

performed at injection rates of 2 and 4 barrels per minute (bpm) constant injection rates. Both continuous and stationary surveys were performed during the testing. Following the injection/flowmeter phase of the testing, the pressure falloff was monitored, and temperature logging was performed to identify the zones within the Mt. Simon that received most of the injected brine.

Table 5-8 summarizes the hydrogeologic testing that was performed in the MCI MW 1 well, and the hydrogeologic parameters that were obtained.

Formation	Target Depth (ft, MD)	Test	Parameters Obtained
Mt. Simon Sandstone	3,370 - 3,390 4,100 - 4,120 4,575 - 4,595 4,802 - 4,822	DST	Initial formation pressure, pressure gradient, water samples for laboratory analysis of chemical and isotopic parameters
Mt. Simon Sandstone	Full interval (2,751 - 4,870)	Composite pumping (drawdown/buildup) test	Composite transmissivity (kb), average hydraulic conductivity, average permeability, skin, radius of influence, formation boundaries, storativity
Mt. Simon Sandstone	4,694 - 4,870 3,918 - 4,870 3,264 - 4,870 3,918 - 4,694 3,264 - 3,918	Single packer injection fall-off tests	Transmissivity (kb), average hydraulic conductivity, average permeability, skin, radius of influence, formation boundaries, storativity
Mt. Simon Sandstone	Full interval (2,751 - 4,870)	Composite injection fall-off test	Composite transmissivity (kb), average hydraulic conductivity, average permeability, skin, radius of influence, formation boundaries, storativity
Mt. Simon Sandstone	Full interval	Dynamic flowmeter (fluid logging and temperature survey) test	Inflow zones, permeability, vertical (profile) distribution
Eau Claire and Mt. Simon Sandstone	Selected intervals: 2,834 - 2,846 2,970 - 2,982 3,270 - 3,282 3,852 - 3,864 4,410 - 4,422 4,684 - 4,696	Hydraulic mini-frac tests	Fracture breakdown pressure, propagation pressure, initial shut-in pressure, closure pressure

Table 5-8: Reservoir tests and parameters collected in the Mount Simon Sandstone during the installation of the MCI MW 1 well.

5.3 Pre-Operational Testing during the Installation of the MCI CCS 3 Well (146.87 (a))

Pre-operational testing was performed during the installation of the MCI MW 1 well; therefore, limited pre-operational testing will be performed during the installation of the MCI CCS 3 well. The pre-operational testing performed on the MCI CCS 3 well will be focused on confirming homogeneity between the MCI CCS 3 well and the MCI MW 1 well.

In addition to the characterization data collected during the installation of the MCI CCS 3 well, information will be collected that will serve as baseline data for the monitoring performed during the operation of the CO₂ injection system. A brief description of the baseline sampling/monitoring is provided in this section, and details are included in the Testing and Monitoring Plan (Permit Section 7).

5.3.1 Deviation Surveys (146.87 (a)(1))

Deviation surveys are obtained as wells are drilled to determine the wellbore path from the surface to the TD of the well. Typically, the tool used to perform deviation surveys is placed in the drill string just above the drill bit and records the inclination of the tool and borehole.

Hole deviation of the MCI CCS 3 well will be maintained to less than 5 degrees off vertical, and the maximum allowable deviation in the well is 5 degrees. If necessary, the wellbore will be steered back to allowable deviation with directional tools (downhole motor or rotary steerable system). Surveys will be taken at the frequency shown in Table 5-9. In general, a deviation will be performed every 300 ft during the drilling of the borehole unless a deviation of >1 degree is measured. As the deviation becomes greater, more frequent surveys will be performed, and remedial actions will be performed to bring the well within specification. More frequent surveys will also be performed while drilling through zones that are known to cause the bit to “walk,” creating a greater risk for deviation.

Range of Deviation	Frequency of Survey
<1 degree	1 survey per every 300 ft. of hole
>1 degree, but < 2 degrees	1 survey per every 240 ft. of hole
>2 degrees, but < 3 degrees	1 survey per every 120 ft. of hole
>3 degrees, but < 4 degrees	1 survey per every 90 ft. of hole
>4 degrees, but <5 degrees	1 survey per every 30 ft. of hole

Table 5-9: Deviation survey frequencies to be taken in the MCI CCS 3 well.

5.3.2 Well Logging: Surface Section (146.87 (a)(2))

Open hole well logs will be acquired prior to setting surface casing as well as after surface casing (surface to approximately 350 ft) is set and cemented. Open hole logs will include gamma ray, density, neutron porosity, SP, resistivity, sonic, and caliper logs. Table 5-10 summarizes the well logs that will be acquired before and after surface casing is set and the purpose of each well log.

The cased hole well logs will be acquired after the surface casing has been set and cemented. Cement integrity will be evaluated through a basic CBL-VDL with a gamma ray tool for depth correlation (Table 5-10).

Open/ Cased Hole	Log Type	Parameters Obtained
Open Hole	Gamma Ray	Lithology
	Density	Porosity, Density
	Neutron Porosity	Porosity
	Spontaneous Potential	Permeability
	Resistivity	Fluid Saturation, Permeability
	Sonic	Porosity, Formation Velocities
	Caliper	Borehole Diameter, Stress
Cased Hole	Cement Bond Log - Variable Density Log	Cement Integrity

Table 5-10: Summary of wireline logs and associated parameters of logging tools to be run before and after surface casing (surface to 350 ft) in the MCI CCS 3 well.

5.3.3 Well Logging: Intermediate Section (146.87 (a)(2))

Open hole well logs will be acquired in the intermediate section of the well (approximately 350 to 2,750 ft) after the intermediate section of the well has been drilled to characterize the deeper geology at the proposed site. Open hole logs will include caliper, gamma ray, SP, resistivity, neutron porosity, density, and sonic. Table 5-11 summarizes the well logs that will be acquired in the intermediate well section and the purpose of each well log. Data from the resistivity log will be used to evaluate the salinity (TDS) of the geologic formations above the caprock and will be used to confirm the Gunter Sandstone as the deepest USDW. If the resistivity logs from both the wells display inconsistent results, samples may be collected from the one or both wells to confirm the log data.

After the intermediate casing string has been cemented, logs will be acquired to evaluate the cement integrity. Cement integrity will be evaluated through a CBL-VDL and an advanced ultrasonic logging tool that will be run with a gamma ray tool for depth correlation (Table 5-11).

Open/ Cased Hole	Log Type	Parameters Obtained
Open Hole	Caliper	Borehole Diameter, Stress
	Gamma Ray	Lithology
	Spontaneous Potential	Permeability
	Resistivity	Fluid Saturation, Permeability
	Neutron Porosity	Porosity
	Density	Porosity, Density
	Sonic - DT	Porosity, Formation Velocities
Cased Hole	Cement Bond Log - Variable Density Log	Cement Integrity
	Ultrasonic Cement Evaluation	Cement Integrity

Table 5-11: Summary of wireline logs and associated parameters of logging tools to be run before and after intermediate casing (350 to 2,750 ft) in the MCI CCS 3 well.

5.3.4 Well Logging: Deep Section (146.87 (a)(3))

Open hole well logs will be acquired in the deep section of the well (approximately 2,750 to 5,000 ft, MD) after drilling this section of the well to characterize the deeper geology at the site. Open hole logs will include caliper, gamma ray, SP, resistivity, neutron porosity, density, dipole sonic, magnetic resonance, and formation imager. Table 5-12 summarizes the well logs that will be acquired in the deep section and the purpose of each well log.

After the long string casing has been cemented, logs will be acquired to evaluate cement quality and provide baseline data for external well integrity. Cement quality will be evaluated through a CBL-VDL log and an advanced ultrasonic logging tool with a gamma ray tool for depth correlation (Table 5-12). Finally, a pulsed neutron log in sigma mode and a temperature log will be acquired to serve as a baseline dataset for the Testing and Monitoring Plan (Permit Section 7.0). The pulsed neutron capture log and temperature log will be performed after drilling muds are no longer present near the well and temperature has stabilized to ensure accurate results from the logging effort.

As part of the preoperational testing program, pulsed neutron capture and temperature logging will also be conducted in the deep monitoring wells to provide baseline data for external well integrity. These logs will also be performed after the wells have returned to static conditions following the installation of the wells. Additional details for baseline monitoring of external well integrity are provided in the Testing and Monitoring Plan (Permit Section 7).

Open/ Cased Hole	Log Type	Parameters Obtained
Open Hole	Caliper	Borehole Diameter, Stress
	Gamma Ray	Lithology
	Spontaneous Potential	Permeability
	Resistivity	Fluid Saturation, Permeability
	Neutron Porosity	Porosity
	Density	Porosity, Density
	Dipole Sonic - DT	Porosity, Formation Velocities
	Magnetic Resonance	Porosity and Permeability
	Formation Imager	Detection of fractures and geologic features
Cased Hole	Cement Bond Log - Variable Density Log	Cement Integrity
	Ultrasonic Cement Evaluation	Cement Integrity
	Temperature	Temperature
	Pulsed Neutron	Lithology, Fluid Saturation, Porosity

Table 5-12: Summary of wireline logs and associated parameters of logging tools to be run before and after long string casing (2,750 to 5,000 ft, MD) in the MCI CCS 3 well.

5.3.5 MCI CCS 3 Well Mechanical Integrity Testing (146.87 (a)(4))

5.3.5.1 Internal Mechanical Integrity Testing (146.87 (a)(4)(i))

Internal mechanical integrity refers to the integrity or seal within the long casing string (i.e., between the long casing string, tubing, and packer). The quality of this seal can be confirmed with a mechanical integrity test (MIT) and annular pressure monitoring. Corrosion of the tubing string can result in internal mechanical issues, and inspection of the tubing will be performed to monitor the tubing for corrosion (Testing and Monitoring Plan, Permit Section 7.0).

After the packer, tubing, and downhole equipment have been installed, and the tubing/casing annulus has been filled with a corrosion-inhibited fluid (a dilute KCl solution with additives), a MIT test will be conducted on the annular space of all the deep wells to ensure that there are no leaks in the tubing, casing, or packer. The MIT will be performed by pumping additional annular fluid into the annulus to increase the pressure to the maximum allowable injection pressure (approximately 1750 pounds per square inch [psi] at the surface). The annular pressure will be monitored for 30 minutes to measure pressure loss. A pressure loss of less than 3% of the initial value would indicate proper internal mechanical integrity. If a pressure loss greater than 3% is observed, the cause of the poor mechanical integrity will be identified and corrected.

Once injection commences, injection pressure, annular pressure, and annular fluid volumes will be monitored continuously to ensure internal well integrity and proper annular pressure is maintained (Testing and Monitoring Plan, Permit Section 7.0).

5.3.5.2 External Mechanical Integrity (146.87 (a)(4) (ii – iv))

External mechanical integrity refers to the absence of fluid movement/leaks through channels between the long casing string and the borehole or the intermediate casing string. Migration of fluids through this zone could result in contamination of USDWs. The external integrity of the wells that penetrate the caprock will be confirmed throughout the project.

Generally accepted methods for evaluating external mechanical integrity include the following:

- Temperature or noise log
- Oxygen-activation logging or radioactive tracer logging

A baseline temperature measurement will be acquired from surface to TD (0 to approximately 5,000 ft) of the injection casing string to provide initial temperature conditions over the well (Section 5.3.4). Temperature measurements acquired after injection has started will be compared to this log to determine if anomalies are present in the subsequent logging events that may be attributed to external integrity issues (Testing and Monitoring Plan, Permit Section 7.0). If the temperature measurement data suggest an issue with external well integrity exists, an oxygen-activation logging run will be performed to evaluate external well integrity with greater sensitivity.

In addition to the baseline temperature log, a CBL-VDL and an advanced ultrasonic cement evaluation log will be run over the entire depth of the long casing string shortly after completion of the MCI CCS 3 well to confirm that the casing string was properly cemented. CBL-VDLs are recorded with sonic tools that detect the bond of the casing and formation to the cement between the casing and wellbore to identify damage. Ultrasonic tools provide higher accuracies and resolutions for cement evaluation.

5.4 MCI CCS 3 Well Core Program (146.87 (b)(d))

Whole and side wall cores were collected from the MCI MW 1 well. These core analyses will serve as the primary geologic characterization for the injection site, and no additional coring efforts are planned for the MCI CCS 3 well. The data from the core analyses performed on the samples collected from the MCI MW 1 well have been incorporated into the static earth and dynamic models discussed in the Project Narrative (Permit Section 1) and the AoR and Corrective Action Plan (Permit Section 2.0). However, if wireline log data gathered from the MCI CCS 3 well display unique results or results that are inconsistent with the data from the MCI MW 1 well or if required by the UIC Director, additional side wall cores may be collected during the installation of the MCI CCS 3 well.

5.5 MCI CCS 3 Well: Fluid Sampling and Analysis (146.87 (b – d))

Characterization of reservoir fluids was performed using samples acquired from the MCI MW 1 well. The analytical results from these samples were used to:

- Determine the deepest USDW. Identified as the Gunter Sandstone at the site
- Provide baseline geochemical conditions in the injection reservoir (Mt. Simon Sandstone), the deepest water bearing zone above the caprock (Galesville Sandstone), and the deepest USDW (Gunter Sandstone)
- Evaluate geochemical reactions that may occur during the injection of the CO₂ that could affect the porosity and/or permeability of the reservoir or caprock formations

The results of the geochemical analyses performed on these samples are discussed and have been incorporated into the Project Narrative (Permit Section 1) and the AoR and Corrective Action Plan (Permit Section 2.0).

The deepest USDW will be confirmed in the injection through resistivity logging and no additional fluid sampling is planned for the MCI CCS 3 well. If the wireline data display inconsistent or unique results compared to the data from the MCI MW 1 well or if required by the UIC Director, additional samples will be collected for geochemical analyses.

The analyses performed on the fluid samples collected from the MCI MW 1 well provide baseline geochemical conditions of the aquifers at the injection site. These data will be used for comparative purposes through the operational/injection and post-injection phases of the project. Additional details on the sampling and analysis of samples collected throughout the remainder of the project are provided in the Testing and Monitoring Plan and Post-Injection Site Closure Plan (Sections 7.0 and 9.0 respectively).

5.6 MCI CCS 3 Well Geomechanical Testing (146.87 (d))

The geomechanical characterization for the site was completed using data from the MCI MW 1 well; however, additional samples will be collected and/or analysis will be performed on the MCI CCS 3 well, if required by the UIC Director. The geomechanical data collected from the MCI MW 1 well were used in the static and dynamic models for the site, described in Sections 1.0 and 2.0 in this permit application.

5.7 MCI CCS 3 Well Hydrogeologic Characteristics (146.87 (e))

Hydrogeologic characterization of the injection site was performed through testing conducted at the MCI MW 1 well (discussed in Section 5.2.7), and limited additional testing is planned for the MCI CCS 3 well. Data from the hydrogeologic testing on the MCI MW 1 well were used in the development of the dynamic flow models to determine the CO₂ plume geometry and distribution. These data are discussed in the AoR and Corrective Action Plan (Permit Section 2.0).

Flowmeter testing is planned for the MCI CCS 3 well to confirm the zones within the Mt. Simon Sandstone which accept the greatest amount of flow during injection. These data will be used to determine the best perforation strategy for the MCI CCS 3 well. The flowmeter testing will be performed by injecting brine into the open borehole after it has been drilled to TD and running a flowmeter tool across the open hole interval. Two flowmeter tests are planned for the MCI CCS 3 well. One test will examine the flow conditions across the entire open borehole (below the intermediate casing) and the other will focus on the Mt. Simon Sandstone by setting a packer at the base of the Elmhurst Formation.

Additional hydrogeologic testing may be performed as required by the UIC Director.

5.8 MCI CCS 3 Well Schedule (146.87 (f))

Marquis Carbon Injection LLC will provide the UIC Director with the opportunity to witness all logging and testing by this subpart. Marquis Carbon Injection LLC will submit a schedule of such activities to the UIC Director 30 days prior to conducting the first test and submit any changes to the schedule 30 days prior to the next scheduled test.

Figure 5-3 and Table 5-13 provide a tentative schedule based on the numbers of days to complete each task. It is anticipated that the drilling schedule can be updated once the Class VI permit is received.

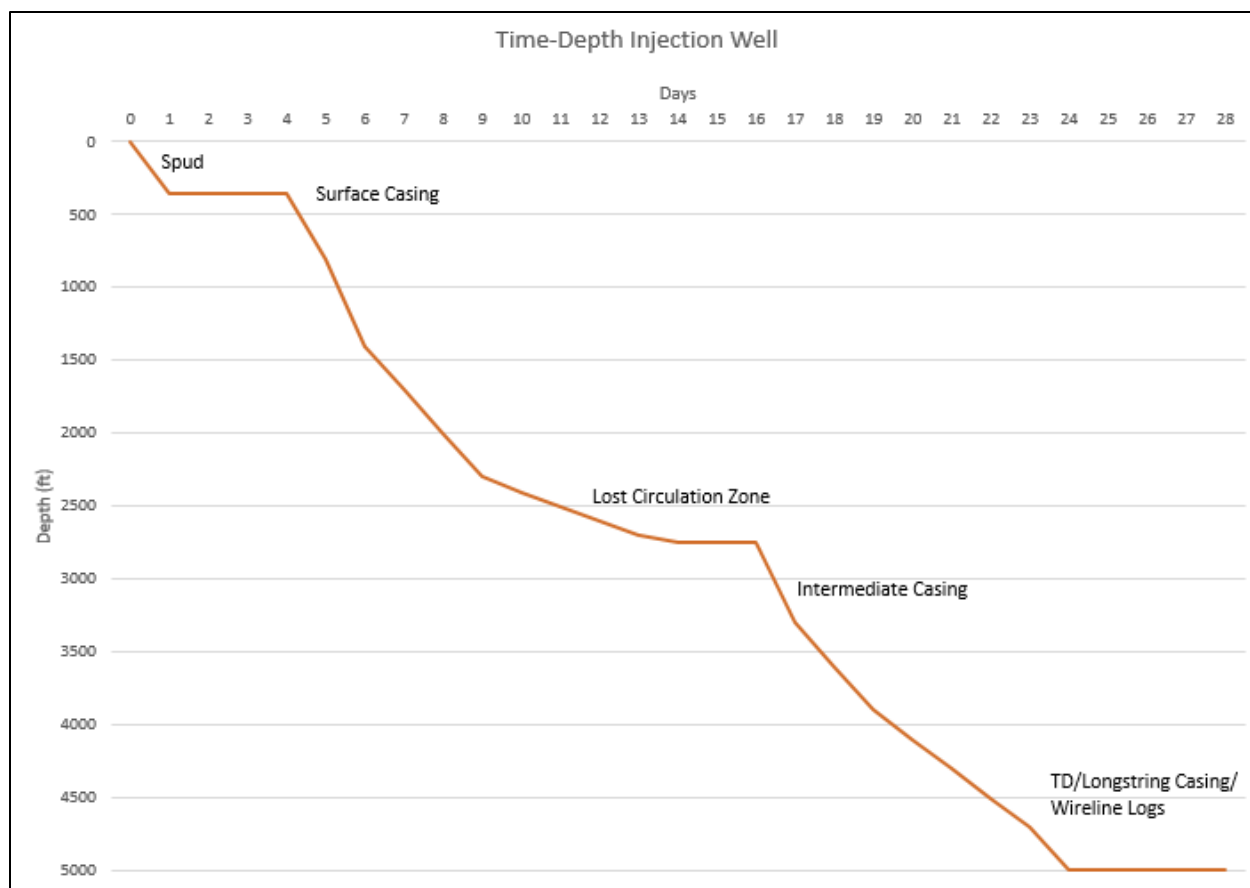


Figure 5-3: Tentative drilling schedule for the MCI CCS 3 well.

Activity	Depth (ft, MD)	Day	Activity	Depth (ft, MD)	Day
Mix Spud Mud	0	0	WOC until 500 psi compressive strength reached. Drill out shoe.	2,750	15
Commence drilling surface hole to approximately 350'	350	1	Run cement bond log at least 48 hours after wiper plug down.	2,750	16
Run surface casing and break circulation.	350	2	Drill ahead	3,300	17
WOC 24 Hours and Run Cement Bond Log.	350	3	Drill ahead	3,600	18
Begin to nipple up BOP after Bond logging.	350	4	Drill ahead	3,900	19
Drill ahead	800	5	Drill ahead	4,100	20
Drill ahead	1,400	6	Drill ahead	4,300	21
Drill ahead	1,700	7	Drill ahead	4,500	22
Drill ahead	2,000	8	Drill ahead	4,700	23
Drill ahead	2,300	9	TD, wireline logs	5,000	24
Drill ahead	2,400	10	Wireline logs	5,000	25
Drill ahead, major LCZ	2,500	11	Run long string casing & cement	5,000	26
LCZ	2,600	12	WOC	5,000	27
LCZ, drill ahead	2,700	13	Run ultrasonic casing evaluation and cement bond logs	5,000	28
Wireline log section, run casing, pump cement	2,700	14			

Table 5-13: Tentative drilling schedule for the MCI CCS 3 well.